Personal Space Vehicle Proposal

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1.Introduction

This document outlines a proposal for the development and manufacture of a fleet of PSVs to provide a low cost, safe and reliable transportation system to the Moon's surface, for both manned and cargo missions. The enabling technology for this system is third Generation (3G) EmDrive propulsion.

The overall programme comprises eight phases with a schedule illustrated in Fig.1.

		Year													
	Programme Phase	1		2		3		4		5		6		7	
1	UAV development	■	■	■											
2	3G Head-start Work			■											
3	PSV development				■	■	■	■	■	■					
4	PAV development				■	■	■	■							
5	PAV commercialisation								■	■	■	■	■	■	■
6	PSV Qualification										■	■			
7	PSV Fleet manufacture										■	■	■	■	
8	PSV Initial Operation												■	■	■

Fig.1

The first phase is the development of an Unmanned Aerial Vehicle (UAV) to provide a demonstration of the lift capabilities of second generation (2G) superconducting EmDrive technology. 2G EmDrive comprises a superconducting EmDrive cavity without acceleration compensation. The Q value achieved by a 2G thruster is limited by the uncompensated Doppler Shifts, which occur during acceleration.

The UAV is described in section 2, with the development programme schedule of 18 months, and Budget of £20 Million, detailed in section 3.

12 months into phase 1, it is proposed to start a short Head-start work package, (Phase 2), to demonstrate the principles of 3G EmDrive. This will be carried out using a linear air track to measure the UAV engineering model (EM) thruster performance, under high acceleration conditions.

Once the UAV has completed a set of demonstration test flights, the PSV development programme, (Phase3), can start. This is estimated to take 3 years at a projected cost of £500 Million, and will result in an unmanned return flight to the moon.

The unmanned demonstration flight will be followed by a series of unmanned and manned flights to complete a Qualification programme, (Phase 6), to meet the regulations defined by the launch country.

Concurrently with phase 6, a manufacturing programme, (Phase 7), to produce a fleet of up to a further 4 PSVs, will be started at a rate of one every 6 months and a projected cost of £200 Million each.

A minimum fleet of 3 PSVs will enable initial operation of manned and cargo flights to build a permanent base on the moon's surface and provide tourist flights. One PSV will always be on instant availability for rescue, which will be a mandatory requirement for tourist flights.

The PAV development programme, (Phase4), could start at the same time as the PSV development. The two vehicles share the same scoutship thrust frame, thus reducing development costs. This would take an estimated 2 years, costing £100Million, and result in a first flight of a prototype air taxi. A PAV commercialisation programme would follow, with the aim of licensing a mass produced air taxi with an estimated price of £60 thousand. The manufacturing process would be similar to that used for a current hydrogen fuelled car.

2.UAV Demonstrator

The purpose of the UAV is to demonstrate that EmDrive flight is possible using a simple low cost vehicle, illustrated in Fig.2.

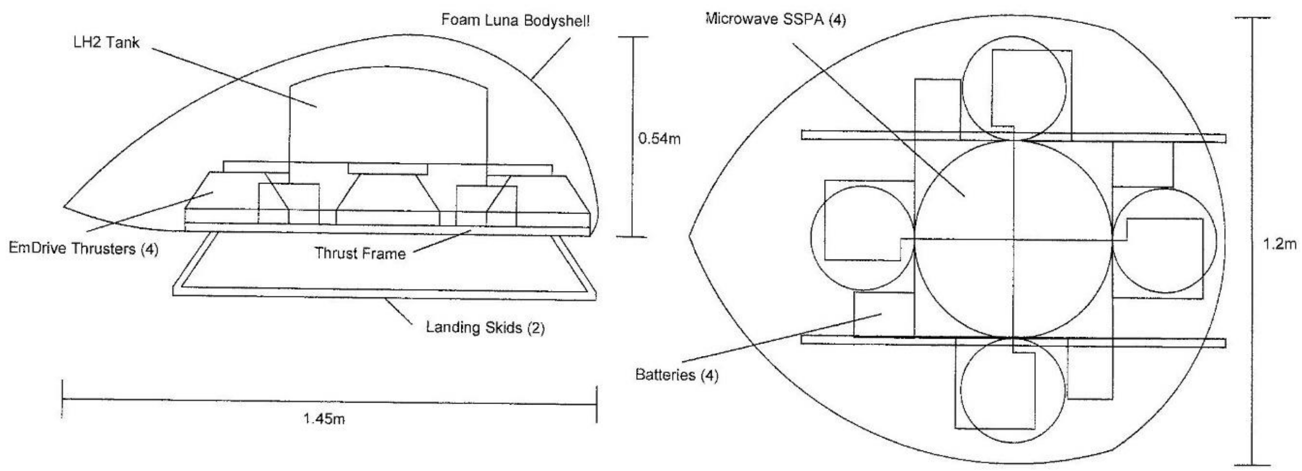

Fig. 2

The 62.5kg UAV is based on a lightweight thrust frame carrying four 2G thrusters with their associated Solid State Power Amplifiers (SSPAs) and batteries.

The thruster design is based on a 2.45GHz cavity operating in TE211 or TE213 mode. Yttrium Barium Copper Oxide (YBCO) thin film end plates are used, which give superconducting operation when cooled with liquid Hydrogen (LH2). This ensures the high Q value required for the specified thrust output of 463N/kW, at an acceleration of .05m/s^2.

Each SSPA incorporates a microwave signal generator and frequency control system and is powered by a 24 Volt, 16 Ampere Hour Lithium Polymer battery. The output section of the SSPA comprises a circulator, a load, and forward and reflected power sensors. The SSPA is rated at 500W minimum output power, and is cooled by the Hydrogen gas which boils off from the cavity cooling system.

A 50 litre thin walled stainless steel tank contains the LH2 supply, which is pressure fed to the cavities via control valves, operated by a control system monitoring the cavity temperature. Additional diverter valves are used as part of the temperature control system of the SSPAs. The hydrogen gas is then vented from the top of the UAV. Internal pressure within the tank is maintained by a safety relief valve.

The Flight control system is based on a standard radio controlled quad-copter system, giving pitch, roll and yaw control by varying the individual thrust of each of the four thrusters. Full telemetry of the propulsion system test data will be incorporated.

The UAV body-shell will be formed of thick foam to provide thermal insulation to limit liquid hydrogen boil-off.

Initial test flights will be carried out at the manufacturing site, with later demonstration flights covering a maximum range of 1.6miles at an altitude below 400 feet. All flights will be within range of sight of the operator, and will be limited to a maximum flight time of 12 minutes, before a refill with LH2 and recharging of the batteries is required. A maximum velocity of 11mph is predicted with a maximum acceleration of .005g.

3.UAV Programme

The 18 month UAV development programme is considered a challenging schedule, and will require a rapid start up, highly paid contract specialist engineering staff, and close project management. A significant proportion of the work will be carried out by sub-contractors who are experienced in microwave and cryogenic engineering. These conditions are typically found in space programmes, particularly military satellites when there is an urgent operational requirement.

However it is recognised that the principles underlying EmDrive operation are not yet well understood. It is therefore recommended that once the core technical and management team have been assembled, they should attend an EmDrive Design Course. This could be run by SPR Ltd at the Prime Contractor premises and is envisaged as a 5 day intensive course.

An outline of the project plan is given in Fig.3, with a resource key given in table 1, and a list of potential sub-contractors for a UK based programme given in Table 2.

Two Engineering Model (EM) Cavity designs will be developed in parallel with separate engineering teams and test rigs. The best performing cavity will then be selected for Flight Model (FM) manufacture and test, where the dual teams and test rigs will facilitate rapid production of the six thrusters. Two thrusters will be used as spares.

An Engineering Model Vehicle will be manufactured and tested using small air turbines in place of the EmDrive thrusters, and used to develop Flight Control software and to test flight procedures.

An outline budget is given in Table 3.

WP		Month																		Resource	
No	Work Package	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Key Staff	Sub cons
1.1	Project Start Up	■	■	■																PC	SPR
1.2	Project Management & Reporting				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	PM PS QA	
2.1	Thruster Design	■	■																		SPR
2.2	SSPA Specification			■																ME MPE	SPR
2.3	EM1 & EM2 Cavity Design	■																		PC	SPR
2.4	Static Test Rig Design	■																		MeE	SPR
2.5	Cryo System Specification			■																TE PE	WC
2.6	Vehicle Design				■	■	■													AE	
2.7	Flight Control System Specification						■													AE	
2.8	Dynamic Test Rig Design							■												MeE	SPR
3.1	EM1 &EM2 Cavity Manufacture		■	■																PC	CE
3.2	Static Test Rigs Manufacture			■																PC	
3.3	EM1 & EM2 Cavity Tests				■	■	■													2ME 2MT	
3.4	FM1 Cavity Manufacture							■												PC	CE
3.5	FM1 Cavity Tests							■	■	■										ME MT	
3.6	FM2 to FM5 Cavity Manufacture									■	■									PC	CE
3.7	FM2 to FM5 Cavity Tests											■								ME MT	
4.1	SSPA1 & SSPA2 Procurement (EM)				■	■	■	■												MPE	MA TMD
4.2	MW Test Equipment Procurement	■	■	■																MPE	
4.3	FM SSPA Procurement (6 off)											■	■	■						MPE	MA/TMD
4.4	Cryo System Procurement				■	■	■													PE	WC BOC
5.1	FM1 Thruster Assembly								■											ME MT	
5.2	FM1 Thruster Static Tests									■	■									ME MT	
5.3	FM1 Thruster Dynamic Tests											■	■							ME MT	
5.4	FM2 to FM5 Thruster Assembly												■	■						2ME 2MT	
5.5	FM2 to FM5 Thruster Static Tests														■					2ME 2MT	
6.1	Vehicle components proc							■	■	■	■	■	■							AE PE	
6.2	EM Vehicle Assembly									■	■									2AE 2AT	
6.3	EM VehicleTests											■	■	■	■					2AE 2AT	
6.4	FM Vehicle Assembly													■	■	■				2AE 2AT	
6.5	FM Vehicle Flight Tests																■	■	■	2AE 2AT	

Fig.3

Key	Staff Requirement	No
PC	Prime Contractor Staff	
PM	Project Manager	1
PS	Project Secretary	1
QA	Quality Manager	1
ME	Microwave Engineer	2
MPE	Microwave Procurement Engineer	1
MeE	Mechanical Engineer	1
TE	Thermal Engineer	1
CE	Control Systems Engineer	1
PE	Procurement Engineer	1
AE	Aircraft Engineer	2
AT	Aircraft Technician	2
MT	Microwave Technician	2
	Total	16

Table 1

Key	Sub-Contractor
SPR	Satellite Propulsion Research
WC	Wessington Cryogenics
MA	Microwave Amplifiers Ltd
TMD	TMD Technologies
CE	Ceraco GmbH
BOC	British Oxygen Company Ltd

Table 2

Budget	£Million
Project Staffing	3.2
Design, Consultancy and Licence	0.8
Microwave Test Equipment	0.4
Test Rig Components	0.2
SSPA EM development (2 off)	1.0
SSPA FM (6 off)	0.6
Superconducting Components	0.2
Cryo System development	1.0
FM Cryo System	0.5
LN2 and LH2 Supply	0.1
Flight Control Components	0.3
In-House Manufacturing	1.5
EM Vehicle Components	1.0
FM Vehicle Components	1.5
Flight Test Support Equipment	0.5
3G Head-start Work	2.0
Project Costs	14.8
Contingency (20%)	3.0
Profit (15%)	2.2
Total Price	20.0

Table 3

4.PSV Description

The 10.4 Tonne, 9m diameter Luna PSV is a fully reusable vehicle, designed specifically for Moon landing and Earth return flights. It is capable of carrying a 4.5 Tonne manned capsule, termed a Scoutship, on top of the vehicle, or a cargo slung underneath the vehicle. The capsule would be designed for a 3 man crew, with a standard docking hatch at the nose of the capsule, and a further hatch and folding ladder in the side of the capsule, for access to the Moon surface. The docking hatch would allow for crew rescue during trans-lunar phases of the flight, with capsule separation and parachute recovery for atmospheric abort scenarios.

A critical design feature is the relatively low technology used in the airframe manufacture. This is a result of the low acceleration that the vehicle is subjected to, (max 0.01g) and the low velocity through the lower parts of the Earth's atmosphere, (max 67mph up to 30km altitude.) Thus mechanical and thermal stresses are low enough for sports car technology, rather than the normal spacecraft technology employed on current programmes.

However any manned flights will still be subject to the regulatory safety and reliability requirements for manned spacecraft. This will include the requirement for full redundancy of the critical power and propulsion systems. A full qualification test period has been included in the overall schedule shown in Fig.1.

The PSV is illustrated in Fig.3.

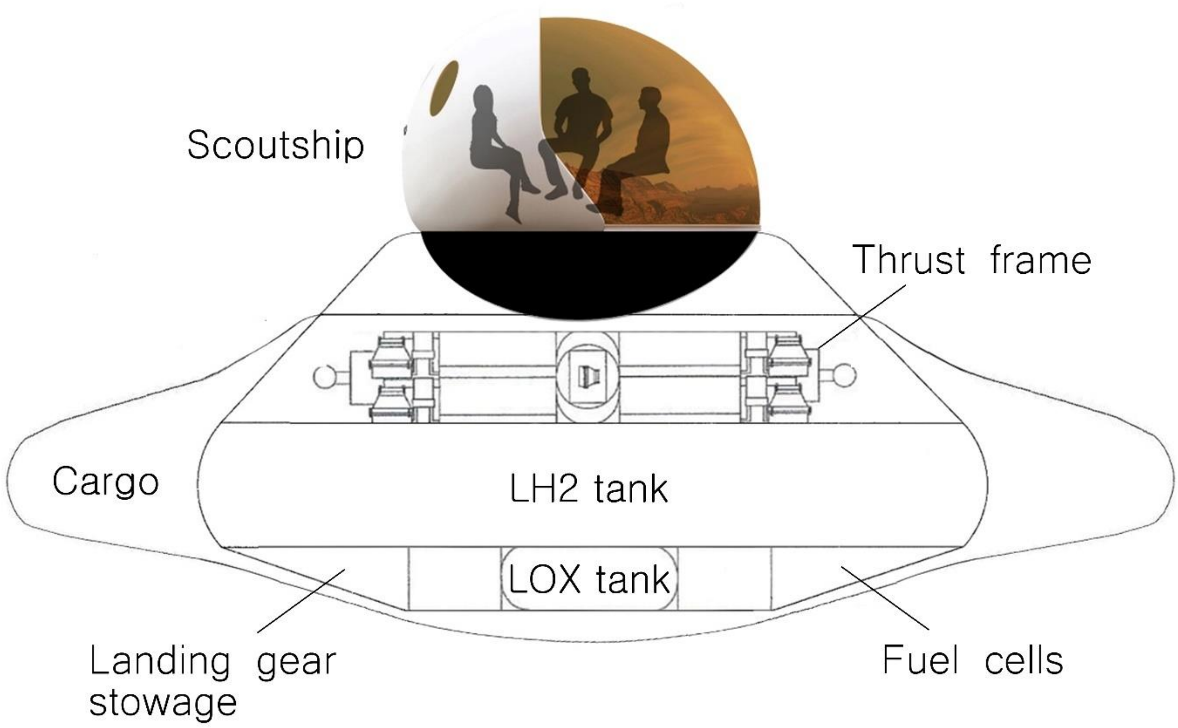

Fig.3

Four, 3G, high Q, EmDrive thrusters provide the primary propulsion for lift and acceleration of the PSV. They operate at 950 GHz in TE211 mode. Each thruster comprises two cavities, each continuously rated at 8.5kW, which operate in pulsed mode, to enable compensation to be applied sequentially by the frequency and axial length control system. They give a specific thrust of 3,857N/kW at a maximum acceleration of $0.1m/s^2$.The thrusters operate in dual redundancy.

Pitch and Yaw control is given by variation of thrust from the four 3G thrusters, whilst Roll control, when full primary propulsion is operating, is given by four 2G thrusters, each mounted on a single-plane, gimbal mechanism. Under the failure of two of the primary thrusters, the 2G thrusters will also give pitch or yaw control. During the cruise phase of the mission, when primary propulsion is off, the 2G thrusters provide full 3-axis attitude control. The 2G thrusters are the same design as those used on the UAV.

LH2 is held in dual redundant tanks with a nominal volume of 43,000 litres, covered in a thick thermal insulation to minimise boil-off whilst on the Moon's surface. Dual redundant fuel cells provide the electrical power to the SSPAs, and are fed by the Hydrogen gas boiled off from the cavity cooling, and Oxygen, stored as liquid Oxygen (LOX) held in two 280 litre tanks.

The lower section of the PSV also provides stowage space for four retractable landing legs and an attachment rail for underslung cargo.

5.PSV Mission

A simple mission analysis has been carried out to determine the major parameters of an Earth to Moon mission. The results of this analysis were used to update the PSV design. Initial inputs were the specific thrust of the primary EmDrive thrusters at a maximum acceleration of $0.1m/s^2$. The mission was divided into 3 phases. The first is an acceleration up through the Earth's atmosphere, including a constant velocity period to limit drag, and into a trans-lunar flight path. The flight path will be designed so that any abort sequence would involve a Moon/Earth figure-of-eight orbit, enabling a rescue using the standby PSV. The rescue PSV would be fitted out for 4 man operation, and have a docking tunnel mounted in the nose of the manned module.

The initial climb is illustrated in Fig.4.

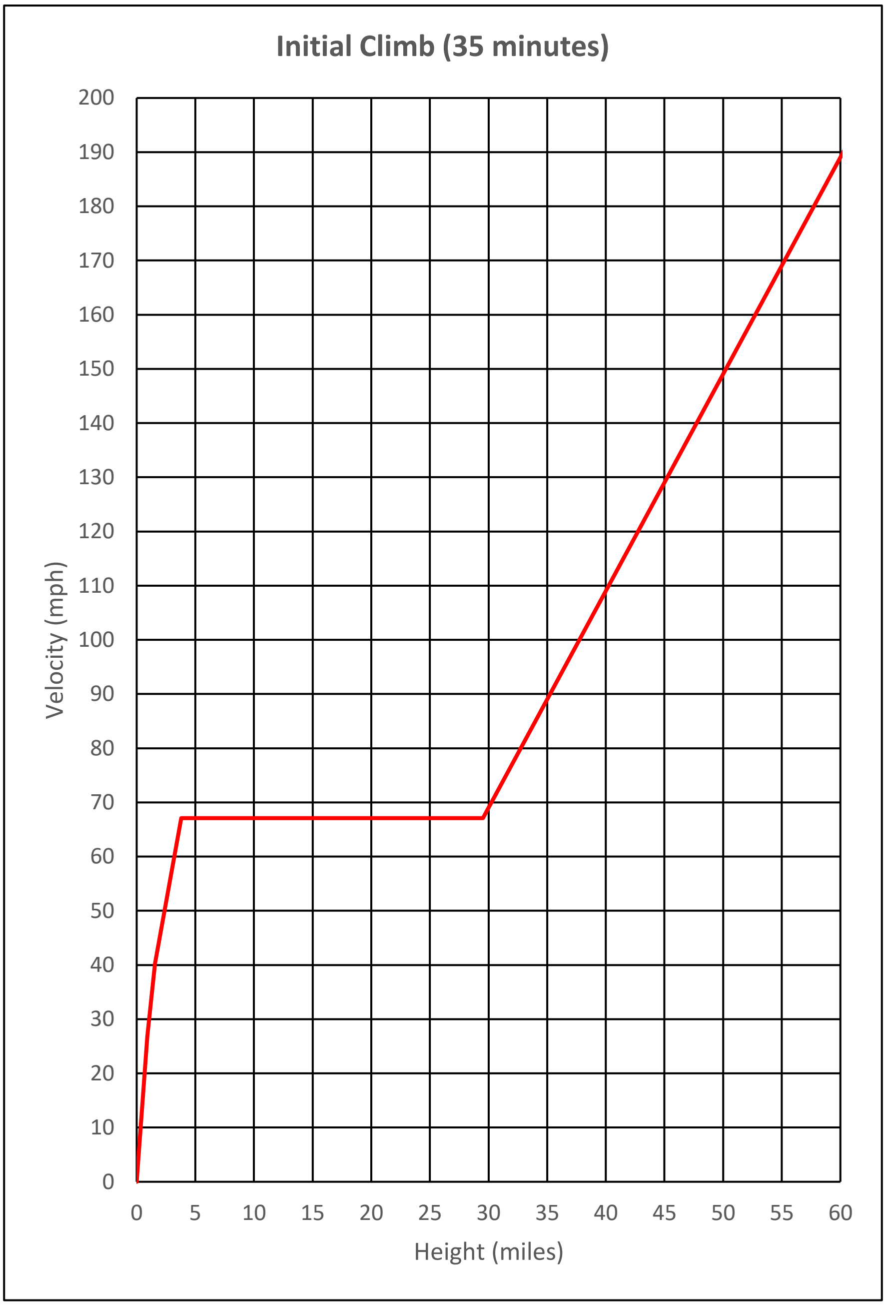

Fig.4

The 13 hour acceleration phase would be followed by a cruise phase, when the primary propulsion is only used for counteracting the much reduced gravity of the Earth. At the start of the cruise phase, Earth's gravity is .03m/s^2, compared to 9.81m/s^2 at the Earth's surface. The Crew will be have been effectively weightless for a few hours, and will be able to use the remaining flight time to adapt. It is important to allow enough time to complete this adaption before the moon landing, to ensure any surface activity can be carried out safely.

The cruise phase lasts a further 11 hours and during this phase the 2G attitude control thrusters will be used to rotate the spacecraft through 180 degrees. The velocity will be kept constant at 10,160 mph throughout the cruise phase.

The 3 phases of the outward flight are illustrated in Fig.5.

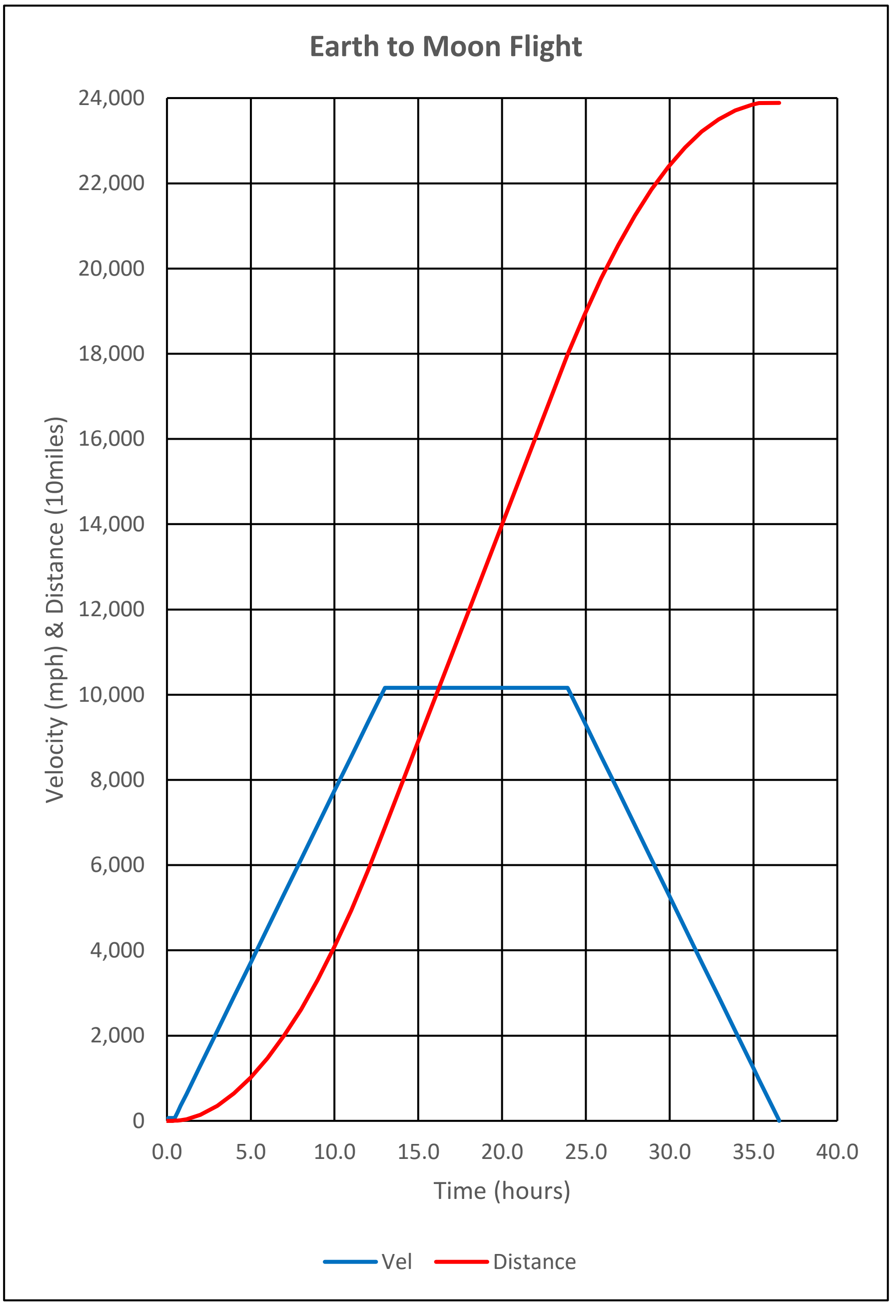

Fig.5

Rotation of the spacecraft during the cruise phase, will enable the primary thrusters to be used for deceleration, which will take a further 13 hours at a rate of - $0.1 m/s^2$. The final part of this phase will involve targeting of the landing site during the low speed vertical descent, followed by a hovering phase, to enable a precision landing close to the surface habitation modules. Access to the manned module will normally be via an aircraft type set of mobile steps. For the early manned flights or in an emergency, egress would be via the folding ladder mounted on the inside of the side hatch. Following a surface stay of a few days, limited by the LH2 boil-off rate, the PSV would return with a full crew, on a flight path which is a mirror image of the outward flight. The total flight time for the outward and return flights would be 72 hours.

A cargo mission, carrying perhaps a Bigelow type inflatable habitation module, would require an extended hovering period, during which the primary propulsion will be used as a sky crane, to position the module for easy docking with existing modules. Once docked, the cargo rail underneath the PSV would release the module and the PSV would launch on its return flight.

6.Operational Considerations

The overall dimensions of the manned module are 5.8m diameter and a height of 2.45m. This gives a relatively spacious internal cabin, allowing for 3 reclining seats, hygiene compartment, and spacesuit stowage, together with controls and life support equipment.

A typical crew would consist of one company pilot and two scientist/observers who would be paying passengers. They would be transported in reasonable comfort to and from habitation modules on the Moon’s surface, which would form a Moon base for scientific and tourism purposes. It is envisaged that for paying passengers, training would consist of a medical, followed by a few days of PSV familiarisation and safety procedures. Spacesuit fitting and training would be necessary, as transfer from the PSV to a habitation module would involve a Moonwalk. Finally rescue training would be mandatory, which would include recovery from a simulated emergency landing on water.

The high level of redundancy built into the PSV power and propulsion systems allow for a significant increase in payload mass, when the vehicle is used in the unmanned cargo configuration shown in Fig.6. A cargo mass of up to 9 Tonnes would be possible.

Fig.6 also shows a PSV with a docking tunnel attached for crew rescue for an emergency during the trans-lunar phase. By attaching the docking tunnel and associated guidance sensors to the cargo rail, a cargo vehicle can become a recovery vehicle. This is also shown in Fig.6, and would be capable of capturing and transporting a failed PSV back to Earth.

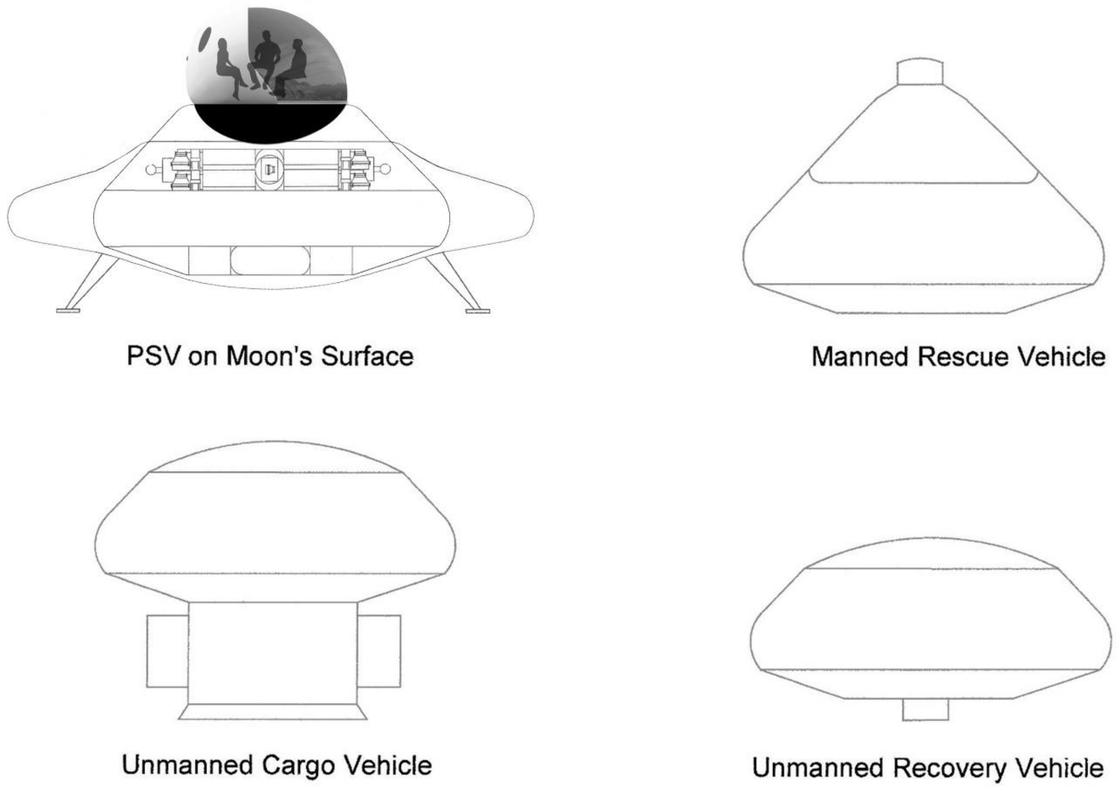

Fig.6

The ground facilities for a fleet of 5 PSVs would comprise two 11,000 sq ft buildings. The buildings would be one Flight Hanger and one Service Hanger. The Flight Hanger would accommodate up to 3 PSVs, and be used for fuelling, loading and first line maintenance. Due to the presence of Liquid Hydrogen and Liquid Oxygen this building would be classed as a Hazardous Area and be subject to special safety conditions.

The Service Hanger would enable routine servicing to be carried out on up to 3 PSVs and accommodate mission control and staff facilities.

As launch and landings are purely vertical, the actual launch and landing site would be no more than a small area of tarmac close to the Flight Hanger. The only need to site the facility at an existing airport or spaceport would be the need to obtain a controlled airspace.

An emergency area for parachute landing of the manned module would need to be designated. This could be at sea, close to one of the proposed spaceports, or in a suitable, adjacent land area.

7. PAV Description

The PAV is a lightweight airborne version of the PSV scoutship, designed for low altitude operation as a two man air taxi. It uses the same basic thrust frame as the PSV, with power and thrust levels compatible with Earth gravity, but with a lower mass vehicle.

The maximum take-off mass is 940kg, giving a maximum operating time of 2.5 hours for full Liquid Hydrogen tanks, containing 2,400 litres. Maximum acceleration levels are restricted to a comfortable 0.4g, whilst the maximum velocity is 230km/hr.

Safety requirements for general aviation certification standards will be met by the eight thrusters giving multiple redundancy, and allowing up to four to fail, whilst maintaining lift. Standby LH2 tanks and batteries will give 10 minutes operation for any emergency landing. The all solid state lift propulsion system, with no moving parts, ensures high reliability with minimum maintenance.

Simple pilot controls based on flight proven drone control software would be incorporated. It is expected that autonomous operation would be rapidly adopted as an option.

The use of Liquid Hydrogen as a renewable fuel offers green, clean operation with just water vapour and cold hydrogen gas as exhaust. Flight characteristics give silent VTOL, and the very important Urban Canyon operation, denied to any rotor driven competitor. Thus a true point to point air taxi service can be offered, without the need to first travel to a heliport.

Fig.7 gives an outline diagram of the PAV.

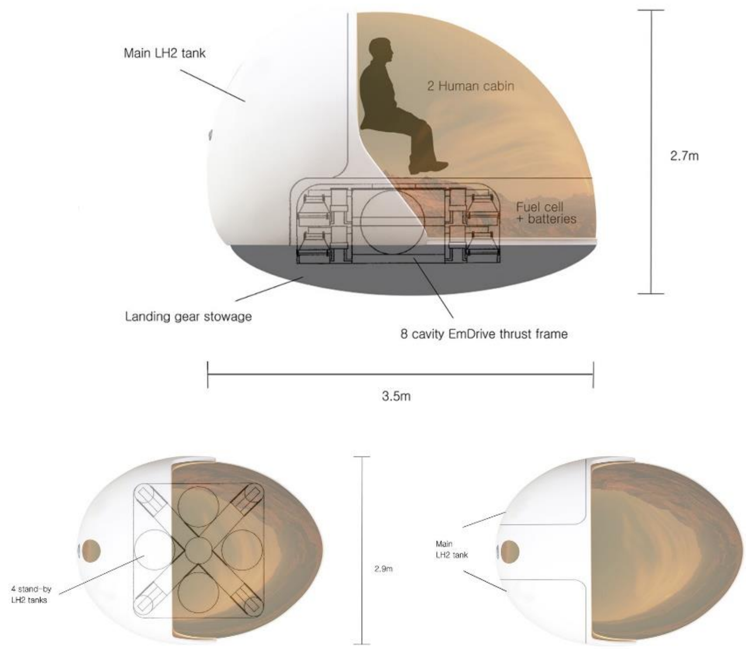

Fig.7

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